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# HORN GROWTH IN MONTANA BIGHORN RAMS

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*Abstract*: Annual growth increments of 59 bighorn rams (*Ovis canadensis canadensis*) from 18 Montana hunting districts were analyzed to test several current hypotheses concerning horn growth. Fluctuating asymmetry measurements were used to test the hypothesis that the small horn syndrome of certain herds resulted from population bottlenecking and a resulting loss of genetic variability. Mineral analyses were used to test the hypothesis that horn size differences can be explained by mineral composition differences which serve as indicators of major soil fertility differences among ranges. Neither of these hypotheses was supported by the analytical results. The general pattern of growth was highest in the middle years of life. The sheep from ranges producing large horns showed greater annual growth from the 2nd or 3rd year through life than did the sheep from ranges yielding smaller horn sizes. Patterns of horn growth in transplanted sheep populations resembled the parent population but had considerably larger annual growth increments. Fluctuating asymmetry values were smallest in the sheep from areas producing small horns. This suggests that loss of genetic variability was not a major influence on these sheep. Asymmetry values in transplanted populations resembled the parent population and sibling populations more than unrelated populations. When climatic effects were evaluated, the annual variation in precipitation accounted for about 30% of the annual variation in horn growth after the effects of age were accounted for.

The horns of bighorn sheep differ somewhat in size among various ranges of this species (Stewart and Butts 1982). It is presumed that this variation is due to both genetic and environmental factors. The relative contribution of each of these factors to the horn variation has never been determined. More detailed information concerning horn growth would be of benefit in managing the species. In an attempt to explore horn growth, data on the annual growth increments from 59 rams representing 18 Montana hunting districts were analyzed.

I wish to thank the many members of the Montana Fish, Wildlife and Parks Department who measured the horns and collected the drill shavings produced in the identification plugging of the horns.

The current study focused upon the fluctuating asymmetry of the annual growth increments, the overall growth patterns, and the relationship of horn growth to climate. Fluctuating asymmetry refers to the bilateral differences in growth seen between the right and left horns of an animal. Such lopsidedness has been used as an index to inbreeding in small populations of cheetah (*Acinonyx jubatus*) (Wayne et al. 1986), grizzly bears (*Ursus arctos*) (Picton et al. 1990) and other species (Leamy 1984). Inbreeding increases the fluctuating asymmetry but environmental stress may increase it as well (Leamy 1984).

## METHODS

Tape measurements of circumference and annual increment length on the outside curve of each horn were made when sheep heads were brought in for registration and marking. All sheep analyzed in this study were killed in 1983 and 1984. The methods used for mineral analysis have been described previously (Picton and Eustace 1986).

STATA 3.1 (Computing Resource Center, Santa Monica, CA.) was used for all statistical analysis. The F test for equality of standard deviations and the T test for equality of means were used. Because of sample sizes and historical and regional affinities, adjacent hunting districts were grouped together for some analyses.

Fluctuating asymmetry was measured by subtracting the measurement of each annual increment of the left horn from that of the right horn. The differences were totalled to give an asymmetry index for the animal. Only data from the base through the fifth increments were used for comparisons because of differences in ages and brooming in the terminal increments. The analysis was repeated using the circumference at each annual increment. An index to the amount of horn tissue laid down each year was obtained by multiplying the annular circumference by the length

**Table 1. A comparison of average horn lengths of bighorn rams over five years of age from different ranges in Montana, 1983 and 1984.**

| Area | n | Mean age | Mean length (cm) |
|---|---|---|---|
| Flint Range | 4 | 8.5 ± 2.5 | 95.3 ± 9.0 |
| Rock Creek | 3 | 6.7 ± 0.6 | 91.8 ± 5.2 |
| Gallatin-Hilgard | 18 | 6.9 ± 1.6 | 77.4 ± 9.3 |
| Highland Mts. | 4 | 5.8 ± 1.5 | 90.2 ± 8.1 |
| Sun River | 8 | 7.3 ± 1.3 | 88.6 ± 7.3 |
| Beartooth-Absaroka | 11 | 7.6 ± 1.4 | 81.5 ± 10.7 |

of the annual increment. This was felt to be more sensitive to the actual metabolic processes of horn growth than the volume estimates used by other workers (Stewart and Butts 1982) because it is a better representation of the actual amount of horn tissue that encloses the volume.

Monthly precipitation totals and growing season data were obtained from weather station records (NOAA 1975-1984). Weather stations with weather fluctuations similar ot that of the bighorn sheep ranges represented by the samples were selected. Thus, the weather station serves as an index to the weather of the sheep range as follows: the Gison Dam weather station data was used for the Sun River hunting districts, the Phillipsburg Ranger Station weather data was used for the Rock Creek and Flint Range sheep ranges, the Wise River weather station was used for the Highland Mountains sheep ranges, Hebgen Lake weather records for the sheep ranges located in the southern portions of the Gallatin and Hilgard mountain ranges., and Cooke City weather for the Beartooth and Absaroka Mountains sheep ranges.

## RESULTS

### Horn Length

The Flint Range, Rock Creek and Highland Mountains areas are notable for their production of large rams (Table 1) over the last 20 years. These areas have all received transplant animals from Sun River. The Beartooth-Absaroka area includes the highest mountains in Montana. Two of the sheep populations in this metapopulation unit have been judged to be in poor condition by population parameters (Martin 1985).

### Asymmetry

Asymmetry as a percentage of total increment length averaged lowest (0.3 percent) in the populations of the south Gallatin - Hilgard range areas. The highest average length asymmetry (3.4 percent) was seen in the Sun River areas. The horn surface area index was used to compare the fluctuating asymmetry of different herds (Table 2). The F test was used to assess the variation in fluctuating asymmetry using the indices of asymmetry. Horns from the Sun River region did not differ in asymmetry from those in the Rock Creek-Flint Range or Highland Mountain areas. Some transplants of sheep from the Sun River were made in these areas since 1960. Sun River sheep also did not differ in asymmetry from the Gallatin-Hilgard sheep but did differ from those in the Beartooth-Absaroka area. Beartooth-Absaroka sheep had significantly less variation in asymmetry than did any of the other areas except for the Highland Mountains.

### Annual Horn Growth

The amount of surface area added to the horn was small during the first year of life, maximum during 3 years of age, and then declined for the remaining years of life (Table 3). On average, the synthesis of horn tissue declined by 14.5 per cent per year after the peak year of growth. The rate of decline of horn growth appeared to be similar for all populations. Regression analysis indicated that age explained between 42 and 91 per cent of the variation in annual horn growth within the various areas (Table 4).

### Relationship of Horn Growth and Climate

Stepwise multiple regression was used to explore the relationship between annual horn growth and monthly total precipitation (Table 4). In general, precipitation explained about 30% of the

**Table 2. A summary of the asymmetry of horn surface area indices for five Montana bighorn sheep areas, 1983 and 1984.**

| Area | n | Mean index asymmetry | Mean % asymmetry | Area differ index (P<.05) |
|---|---|---|---|---|
| Flint-Rock | 11 | 13.4 | 0.69 | Beartooth |
| Highland Mt | 5 | 12.7 | 0.57 | |
| Sun River | 8 | 10.2 | 0.54 | Beartooth |
| Gallatin-Hilgard | 19 | 9.5 | 0.57 | Beartooth |
| Beartooth-Absaroka | 11 | 8.8 | 0.54 | All except Highland |

variation in horn growth remaining after the effects of age were accommodated. However, there were considerable differences among areas (6.9% to 77.8%).

**Relationship of Annual Horn Growth and Mineral Content**

The Fe, Al, Mg, P, Ca, Pb and Zn levels reported previously (Picton and Eustace 1986) did not show significant correlations with the annual growth increments. No consistent patterns emerged from the data.

**DISCUSSION**

The Flint Range, Rock Creek, and Highland Mountain areas have been prime areas for the production of large horns for a number of years. These areas have received transplant of sheep from the Sun River population. The Flint Range and Rock Creek area had existing populations which were supplemented by the transplants. The Highland Mountains population represents an entirely new population on historic range. This population is characterized by exceptionally rapid

**Table 3. A comparison of annual horn growth using the surface area indices for five population units in Montana, 1983 and 1984.**

| Age | Flint-Rock | Highland | Sun River | Gallatin-Hilgard | Beartooth-Absaroka |
|---|---|---|---|---|---|
| 1 | 18.9 | 12.5 | 17.7 | 9.2 | 6.9 |
| 2 | 83.1 | 121.6 | 98.1 | 62.2 | 54.4 |
| 3 | 105.4 | 127.8 | 86.2 | 76.6 | 66.6 |
| 4 | 90.7 | 93.1 | 69.5 | 66.2 | 63.5 |
| 5 | 72.5 | 52.0 | 54.0 | 57.1 | 58.2 |
| 6 | 50.1 | 37.7 | 36.8 | 36 | 45.6 |
| 7 | 43.1 | - | 31.7 | 35.6 | 32.3 |
| 8 | 27.5 | - | 17.6 | 18.7 | 21.4 |
| 9 | 15.9 | - | 9.2 | 16.3 | 15.1 |

**Table 4. The proportion of annual horn growth explained by age, precipitation, or unexplained. The months in which precipitation has a major positive or negative effect are given.**

| Area | Age | % Age explain | %Ppt explain | % Un-explain | Important months | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | N | D | J | F | M | A | M | J | J | A | S | O |
| Flint | <2 | 42 | 6 | 52 | | | | F | | | | | | | | |
| -Rock | 3+ | 74 | 7 | 19 | | | | | M | A | M | J | | | | O |
| Highland | <2 | 91 | 7 | 3 | | | | | | A | M | | | | S | |
| | 3+ | 68 | 22 | 10 | | | | | | | M | J | J | | S | O |
| Sun River | <2 | - | - | - | | | | | | | | | | | | |
| | 3+ | 71 | 2 | 27 | N | | J | F | M | | | J | | | | |
| Gallatin | <2 | 69 | 6 | 25 | N | | | | M | A | M | J | J | A | | |
| Hilgard | 3+ | 55 | 8 | 37 | N | | | | M | A | M | J | J | A | | |
| Beartooth | <2 | 47 | 7 | 46 | | D | | F | M | A | | | | | | |
| Absaroka | 3+ | 74 | 5 | 21 | | | J | F | | A | | J | | | | O |

horn growth rates in the second and third years of life which carried over into the fourth year in all except the Sun River. Historically, the Sun River population persisted for many years at ecological carrying capacity and then underwent a major expansion following reduction in the number of elk (*Cervus elaphus*) on the range (Picton 1984). The sheep for the transplants were obtained during this period of increase.

Steward and Butts (1982) proposed that the difference in horn size among different populations can be related to population bottlenecking and consequent inbreeding in this century. Fluctuating asymmetry can be used to test this hypothesis because it is believed to increase as inbreeding increases (Leamy 1984). Inbreeding reduces the effectiveness of growth control resulting in an increase in "lopsidedness" in the animal (Leamy 1984, Palmer and Strobeck 1986). Thus, fluctuating asymmetry should increase in areas that historically had a major period of population constriction. The Gallatin-Hilgard and Beartooth-Absaroka areas might be expected to show high levels of asymmetry but instead were notable for the low levels of asymmetry. The latter population lies northeast of Yellowstone Park; the former area is northwest of the Park. The fluctuating asymmetry analysis does not support the population bottlenecking hypothesis. The apparent lack of a significant difference in asymmetry between the Highland herd and the Beartooth-Absaroka sheep may have been due to the small number of samples for the Highland herd (n=5).

Hypotheses that deficiency or insolubility of particular minerals interfered with horn growth (Picton and Eustace 1986) were tested using this detailed database. The analysis of annual horn growth patterns and their mineral content produced no support for the hypotheses that these minerals were limiting. Schwantje (1986) pointed out that low levels of copper and selenium can produce subclinical problems in domestic sheep and perhaps bighorn sheep. Although Cu levels were closely examined for a relation to horn growth, none was found. While horn tissue can be expected to be a physiological recorder of conditions present during its formation, it is probably not as sensitive as the live tissue used by Schwantje (1986).

The pattern of horn growth seen here, with peak growth during years 2, 3 and 4 is similar to the inverted U pattern described for Dall sheep (*Ovis dalli dalli*) (Bayer and Simmons 1984, Konig and Hoefs 1984). While it cannot be specifically confirmed, it appears that areas notable for large horn sizes have particularly high rates of growth in the early years of life.

The relationship of climate to the productivity of sheep also has been reported (Picton 1984). The use of weather station precipitation represents a rough assessment of the importance of climate and the probable effects of year to year variation in nutrition on horn growth. Use of an effective precipitation model for each range area combined with distribution information would improve the assessment. Both positive and negative relationships were seen when comparing monthly precipitation and horn growth. However, I feel that a more detailed analysis is necessary before it can be concluded whether increased precipitation during a given month will have a positive or negative effect on horn growth.

## MANAGEMENT IMPLICATIONS

In management terms, it appears that the sheep of the high altitude ranges surrounding Yellowstone Park may represent an adaptive suite that includes smaller tightly curled horns. It is suggested that further evaluation be done before supplemental plants of sheep of the larger curl lineages are made in the area. Comparable data from the neighbouring herds in Wyoming (Shoshone River and Whiskey Mountain areas) would be particularly valuable. Bighorn sheep from the Sun River lineage seem particularly able to make use of new habitats and should be considered when making reintroductions into currently unoccupied ranges.

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